DCIEM No. CR 2001-080

RESEARCH AND DEVELOPMENT OF AN ADVANCED PERSONAL LOAD CARRIAGE SYSTEM PHASES II AND III

Section C: Analysis of Seven Pack-Based Systems using Human FAST Trials

by

J. Doan
J. Stevenson*
T. Bryant
E. Morin
D. Andrews

Queen's University*
Kingston, Ont. K7L 3N6

Project Manager:
Joan M. Stevenson
(613) 545-6288

PWGSC Contract No. W7711-5-7273/001/TOS

on behalf of
DEPARTMENT OF NATIONAL DEFENCE

as represented by
Defence and Civil Institute of Environmental Medicine+
1133 Sheppard Avenue West
Toronto, Ontario, Canada
M3M 3B9

DCIEM Scientific Authority:
Major Linda Bossi
(416) 635-2197

October 30, 1997

© HER MAJESTY THE QUEEN IN RIGHT OF CANADA (2000)
as represented by the Minister of National Defence

Analysis of Seven Pack-Based Systems Using Human FAST Trials

Executive Summary

This section outlines the methodology used by the Ergonomics Research Group in conducting standardized human trials for the evaluation of load carriage systems (LCS). The results from these First Assessment and Standardized Testing (FAST) trials pertained to two areas of interest of the Advanced Personal Load Carriage Research group. Firstly, information on subject preferences was useful in increasing the knowledge of LCS design quality, and the effect of different designs and design interactions on human performance. Secondly, the FAST Trials provided human factors results for correlation with LC Sim data. Results from LC Sim testing can be found in Section B, while the outcomes of the correlational analysis can be found in Section D. Specific areas of concern for this project included integration of marching and battle orders, physical costs associated with the incorporation of fragmentation protection into the LCS, and the general performance of different marching and battle order designs.

Twenty eight experienced military subjects were assigned four of the load carriage systems (LCS) over the course of four consecutive trials. In each trial, subjects completed a march of 5.0 km over level ground as well as five activity stations (AS). Each lap of the march (1.0 km) was followed by one of these AS's, presented to subjects in random order. Subject responses were elicited immediately following each AS. Following one complete trial, a subjective response summary was collected, rating the acceptability of the LCS. Subjects also rated their perceived discomfort, due to the LCS, experienced during the test. After doffing the test ruck, subjects completed five different AS's designed to test features and function of the battle order component of the test LCS. Again, subjective response was gathered pertaining to performance in each test, overall impressions, and perceptions of discomfort. Following completion of four trials subjects ranked the four LCS's they tested in terms of balance, comfort, fit, and manoeuvrability.

Table of Contents

Executive Summary i

Table of Contents ii

List of Figures iii

List of Tables iv

1.0 Introduction 1

2.0 FAST Trials Test Protocol 2

3.0 FAST Trials Test Results 14
- **3.1 Base System Testing** 15
- **3.2 Integration Testing** 21
- **3.3 Fragmentation Vest Testing** 25
- **3.4 Battle Order Testing** 32

4.0 FAST Trials Test Discussion 36
- **4.1 Base System Testing**
  - 4.1.1 Main Findings 36
  - 4.1.2 Conclusions 37
- **4.2 Integration Testing**
  - 4.2.1 Main Findings 39
  - 4.2.2 Conclusions 40
- **4.3 Fragmentation Vest Testing**
  - 4.3.1 Main Findings 41
  - 4.3.2 Conclusions 42
- **4.4 Battle Order Testing**
  - 4.4.1 Main Findings 43
  - 4.4.2 Conclusions 44

5.0 Conclusions and Recommendations 45

6.0 References 46

Annex C.1 FAST Trials Subject Questionnaires 47

List of Figures

FAST Trials Test Protocol

Figure 2.1 Path of marching order LCS trial 6
Figure 2.2 Path of battle order LCS trial 11

FAST Trials Test Results

Figure 3.1-1 Boulder hop, one of five marching order activity stations in the FAST Trials .. 15
Figure 3.1-2 FAST Trials investigator leading subject through marching order static tasks test 16
Figure 3.2-1 Subject in CVNF receiving aural temperature measurement 24
Figure 3.3-1 Battle order testing of fragmentation vests 26
Figure 3.4-1 Prone rifle firing test of LCS battle order 37

List of Tables

FAST Trials Test Protocol

Table 2.1 Subject anthropometrics for LCS testing in FAST Trials 3
Table 2.2 Description of load carriage systems (LCS) 5
Table 2.3 Description of marching order activity stations 8
Table 2.4 Description of marching order static tasks test 9
Table 2.5 Description of battle order systems 10
Table 2.6 Description of battle order testing activity stations 12
Table 2.7 Description of battle order static tasks test 13

FAST Trials Test Results

Base System Testing

Table 3.1-1a Subjective performance measures from FAST Trial marching order activity station responses 17
Table 3.1-1b Combined averaging of marching order activity station question responses into subjective performance variables 17
Table 3.1-2 Marching order static performance measures for base systems 18
Table 3.1-3 Marching order activity station summary ratings for base systems 19
Table 3.1-4 Ratings of perceived discomfort for marching order testing of base systems . . . 19
Table 3.1-5 Overall ratings for base systems 20

Integration Testing

Table 3.2-1 Subjective performance measures from FAST Trial marching order activity station responses for systems in integration testing 21
Table 3.2-2 Marching order static performance measures for integrated systems 22
Table 3.2-3 Marching order activity station summary rankings for integrated systems 23
Table 3.2-4 Ratings of perceived discomfort for marching order testing of integrated systems 24

List of Tables (continued)

Fragmentation Vest Testing

Table 3.3-1 Subjective performance measures from FAST Trial marching order activity station responses 27
Table 3.3-2 Marching order static performance measures for fragmentation testing 28
Table 3.3-3 Marching order activity station summary ratings for fragmentation testing 29
Table 3.3-4 Ratings of perceived discomfort for marching order testing of fragmentation base systems 30
Table 3.3-5 Overall ratings for fragmentation systems 30
Table 3.3-6 Physiological response to marching order testing of fragmentation systems ... 31

Battle Order Testing

Table 3.4-1 Battle order activity station responses for test systems 33
Table 3.4-2 Battle order static task responses for test systems 34
Table 3.4-3 Battle order testing summary results for test systems 35
Table 3.4-4 Ratings of perceived discomfort for test systems in battle order testing summary 35

Analysis of Seven Pack-Based Systems Using Human FAST Trials

1.0 Introduction

There were three main objectives of this study component. First, the base system testing capabilities of seven load carriage systems were determined, based on human factors testing over a series of standardized tasks. Second, alternative battle order designs were evaluated by subjects during a course of physical tasks. Finally, physiological response to the integration of a fragmentation vest with load carriage was measured, along with subjective response.

Military operations involve the movement of personnel and equipment into areas of conflict. These areas are often difficult to access, and are typically equally inhospitable once the military force has arrived. The ability to maintain a supply of food and water, as well as establishing effective shelter, communications, and weapons defense is critical to the survival of a soldier in these circumstances. For this reason, the personal load carriage system (LCS) or 'rucksack' has long been used to transport military and personal items into battle (Renbourn, 1954). The cost of this portability is discomfort, leading to injury, for soldiers who carry large loads, or carry loads improperly. Injuries due to load carriage, such as skin pressure sores, restricition of blood flow to arms, muscle fatigue, and physiological costs have been well documented (Datta and Ramanathan, 1971; Winsmann and Goldman, 1976; Legg and Mahanty, 1985; Balogun et al., 1986; Holewijn, 1990; Holewijn and Lotens, 1992). However, research into the capabilities of various LCS in preventing these injuries has not focused on the design of the pack, only the location of the load.

Standardized testing of load carriage systems was previously performed by the Ergonomics Research Group at Queen's University as two separate tests; agility trials in an obstacle course setting, and extended march testing on level terrain (Stevenson et al., 1995). The test procedure described in this report, referred to as the First Assessment and Standardized Testing (FAST) trials, was a combination of these two tests, with the addition of typical military style tests. The hypothesis was that this hybrid test design would provide a more clear indication of LCS requirements, and subsequently allow for a more complete design analysis.

2.0 FAST Trials Test Protocol

Subjects

Testing was performed on twenty eight (28) Canadian Forces (CF) subjects. Anthropometric data for these subjects are included in Table 2.1. All subjects were infantry soldiers from the same CF unit and as such were equally familiar with the rigours of load carriage as a military operation. All subjects were informed of the nature of the testing, and they provided written consent to participate in the study.

Load Carriage Systems

The Load Carriage Systems (LCS) tested were selected from exisiting military systems. A description of each system can be found in Table 2.2. All packs were filled to maximum dimensions with rigid foam. This foam contained the payload for each pack (MEAN 27.5 kg, SD +/- 1.0 kg), and kept this load in a consistent position All battle orders were filled with a battalion standard operational load.

Testing - Marching Orders

LCS were assigned to all subjects in an incomplete block design. Subjects received instructions and assistance in adjusting their test LCS for maximal fit. Subjects were also instrumented with heart rate monitors (Vantage XL™, Polar Industries) and 5 skin surface thermistors (YSI Series 400™), located on the chest, forearm, wrist, inside thigh, and calf. Data from the skin surface thermistors were collected with a portable data logger (SmartReader™, ProLogics Industries). All data were downloaded to a portable computer immeadiately following marching order testing. The purpose of the physiological data collection was to provide a comparison between load carriage with and without fragmentation protection. To this end, each subject wore a prototype fragmentation vest for two of four trials, with trials randomized only by frag vest size availability.

Figure 2.1 is a flowchart outlining the path of one marching order LCS trial. Subjects began their first march lap (1000 m) at one minute staggered intervals. The march occured on level terrain and subjects were asked to work at a pace that they could maintain in all four trials. When subjects returned to the testing centre, their elapsed time was recorded and a measurement of core

P516230.PDF [Page: 11 of 86]

Table 2.1. Subject anthropometrics for LCS testing in FAST trials.

Subject	Rank	Gender	Age (years)	Years of Military Service	Standing Height (cm)	Weight (kg)	Neck Circumference (cm)	Chest Circumference (cm)	Waist Circumference (cm)	Buttock Circumference (cm)	Biacromial Breadth (cm)	Waist-Back Length (cm)
1	Corporal	Male	22	5.5	185.4	91.4	40.0	102.5	86.0	103.5	44.0	51.0
2	Corporal	Male	25	6	170.2	70.1	36.0	91.5	83.5	100.0	40.0	45.0
3	Corporal	Male	25	6	179.1	90.7	41.0	111.0	92.5	106.0	46.0	47.0
4	Corporal	Male	26	5	165.1	68.0	38.5	94.0	80.0	94.0	38.0	42.5
5	Trooper	Male	22	3	176.5	83.7	40.0	103.5	84.0	105.5	44.0	46.0
6	Corporal	Male	24	6	179.1	77.1	36.0	98.5	83.0	100.0	42.0	46.0
7	Corporal	Male	26	4	179.1	82.5	39.0	101.5	82.5	104.5	42.0	50.0
8	Trooper	Male	24	3	174.6	80.3	39.5	103.5	85.0	99.0	43.0	48.5
9	Corporal	Male	27	6	167.6	82.5	40.5	103.0	86.0	99.5	46.0	48.0
10	Corporal	Male	25	4	180.3	80.1	38.0	102.0	82.0	99.5	44.0	49.0
11	Corporal	Male	27	8	188.0	86.3	39.0	102.0	87.0	103.5	41.0	47.0
12	Sergeant	Male	29	8	184.2	88.2	39.0	104.5	81.0	105.5	42.0	53.0
13	Trooper	Male	24	3	165.1	71.2	38.0	103.5	82.0	96.5	45.0	44.5
14	Corporal	Male	26	7	183.5	71.2	37.0	97.5	77.0	93.0	37.0	45.0
15	MCorporal	Male	28	9	178.4	84.4	37.0	101.5	88.0	103.5	46.0	47.0
16	Corporal	Male	26	7	182.9	98.4	42.0	111.5	92.0	109.0	47.0	48.0

P516230.PDF [Page: 12 of 86]

Table 2.1 (continued).Subject anthropometrics for LCS testing in FAST trials.

17	Corporal	Male	29	5.5	181.0	75.1	36.5	93 5	80.5	97.0	44 0	44.5
18	Corporal	Male	23	4	189 2	86.2	40.5	94.5	82.0	101.0	46.0	48 0
19	Corporal	Male	25	7	185.4	97.1	38.0	110 0	94.0	112.0	47.0	51.0
20	Corporal	Male	24	6	184 8	92 5	41 0	108.0	90 0	103.0	45.0	49.0
21	Corporal	Male	24	6	191.8	91.2	39.5	107.0	86.0	104.0	47.0	50.5
22	Private	Male	26	1	180 3	80.3	40.0	99 0	77.5	96 0	41.0	46.0
23	Private	Male	24	1	175.3	84 4	40 0	101 0	82.5	102.5	45.0	49 5
24	Private	Male	24	1	184.8	89 3	39 0	98.0	82.0	103.0	45.0	50.0
25	MCorporal	Male	34	11	174.0	93 9	42.5	107.0	98.0	107.0	43 0	47.5
26	Private	Male	23	1	168.9	57.6	35.0	81 5	72.0	90.5	39 0	42.5
27	MCorporal	Male	28	11	168.3	77.5	39.0	99.0	85.0	101 0	45.0	48.0
28	Private	Male	25	6	167.6	68.5	37.5	92 5	73.0	95.5	44.0	43.0
Mean			25.5	5.4	178 2	82.1	38 9	100.8	83.9	101.3	43.5	47.4
SD			2.5	2.7	7 6	9 8	1.8	6 6	5.8	4.9	2.7	2 7
Safework/ ANSUR 50 %le					175 6	78.5	40 8*	98.7	85 6	98 1*	39.7*	50 6*

* - significant difference at t(0.05, 27).

P516230.PDF [Page: 13 of 86]

Table 2.2 Description of load carriage systems (LCS).

Symbol	Physical Size (cm) (H X W X D)	Description	Battle Order
A	52 X 34 X 17	- long, narrow shape with sleeping bag contained in bottom - internal frame, adjustable lumbar pad, padded hip belt, sternum strap	- webbing
B	45 X 32 X 18	- short, narrow shape with modular pockets for sides, sleeping bag contained - internal frame, unpadded hip strap	- webbing
CW	63 X 37 X 30	- wider shape with sleeping bag slung on bottom - external wire frame, unpadded hip strap	- webbing
CV	63 X 37 X 30	- same load carriage as CW	- load carriage vest
DW	60 X 37 X 30	- wider shape with sleeping bag slung on bottom, external plastic packboard frame - adjustable lumbar pad, adjustable shoulder yoke, padded hip belt, sternum strap	- webbing
DV	60 X 37 X 30	- same load carriage as DW	- load carriage vest
E	54 X 34 X 30	- short, wide shape with sleepingbag exposed on top - external tubular frame, unpadded hip strap	- webbing

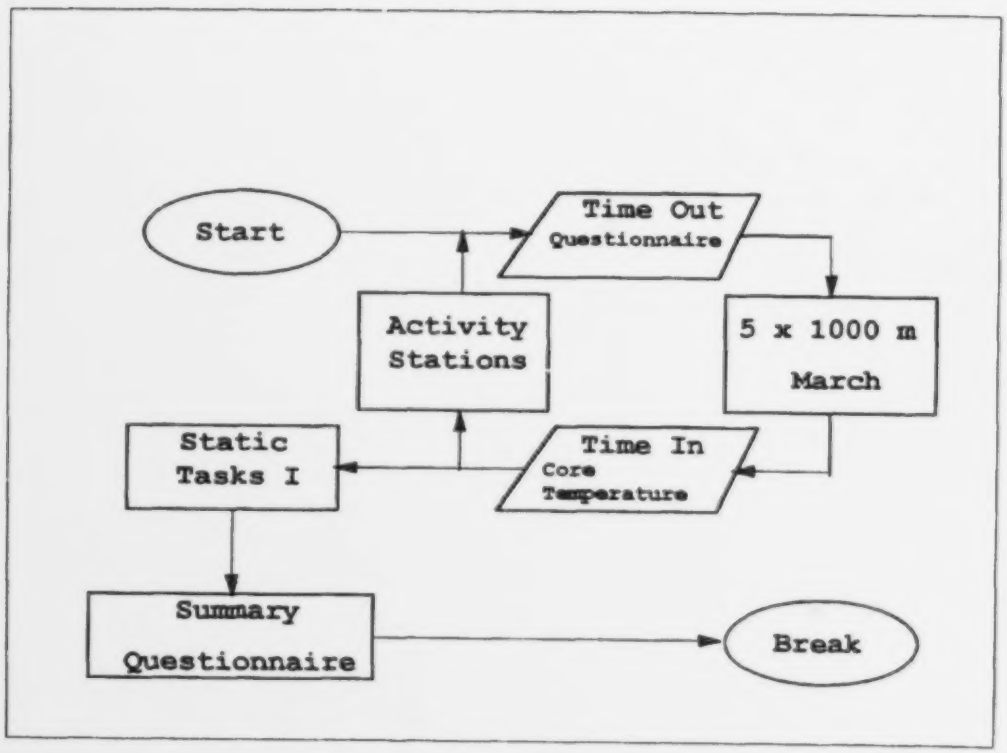


Figure 2.1 Path of marching order LCS trial.

temperature was taken with an infra-red ear thermometer (First Temp Genius™, Sherwood Medical). Subject core temperature was used as a safety measurement to prevent heat exhaustion. Subjects were then directed to one of four marching order activity stations (AS), as described in Table 2.3. AS were randomized for each trial for all subjects to prevent any learning effect. Subjects finished the assigned AS and then completed the questionnaire page for that AS. Copies of the questionnaires for the four marching order AS are available in Annex C.1. Following completion of the AS questionnaire, subjects began another march lap. Time out of the testing centre was also recorded, providing an interval time for each AS. Subjects completed five march laps and four AS in one trial. After the final march lap, subjects attempted a series of investigator-led static tasks (Table 2.4) in an effort to evaluate any reduction in range of motion imposed by the LCS. Following the marching order static tasks test, subjects completed a marching order summary questionnaire (Annex C.1) for that trial. This summary included a human torso pictogram (front and back) with a numerical scale which allowed subjects to rate their perceived discomfort during the trial.

Testing - Battle Orders

Battle order testing, as depicted in Figure 2.2, followed much the same format as the marching order testing. Battle orders tested are described briefly in Table 2.5. Four battle order activity stations (AS), listed in Table 2.6, were completed by each subject, in a randomized order. Heart rate and skin temperature data collection equipment was removed prior to this testing, to prevent any damage during the geometric exclusion tasks. Questionnaires, found in Annex C.1, were completed following each AS. Following the activity stations, a series of battle order static tasks (Table 2.7) were conducted under the supervision of an investigator. Subjects rated their range of motion while performing these simple tasks. After the static tasks AS, subjects completed a full circuit of the marching order AS to familiarize themselves with the dynamic abilities of the test battle orders. A battle order summary (Annex C.1) was then completed, similar to the marching order section.

After all trials had been completed for one group, subjects were asked to rank the four LCS they tested in terms of balance, comfort, fit, and manoeuvrability, and to provide comments on the performance of each system. These questionnaires can also be found in Annex C.1.

Table 2.3 Description of marching order testing activity stations (AS).

Activity Stations	Station Name	Description
1	Bent Balance Beam	- 10 m balance beam, 9 cm wide w/ 65 degree directional changes
	Boulder Hop	- 7 stones, 25 cm diameter w/90 degree directional changes
2	Straight Balance Beam	- 10 m balance beam, 9 cm wide
3	Fence Climb	- scale and descend 1.2 m fence
	Agility Run	- 10 pairs pylons (0.75 m apart) in slalom course over 10 m
4	Side Slope Walk	- 7.5 m long w/ 26 degree side slope angle
	Forward Ramp Climb	- 4.5 m long w/ 21 degree angle of elevation

Table 2.4 Description of marching order static tasks test.

Task	Task Name	Description
1	Hands above head	- reach both arms above head together - drop one arm, drop second arm, raise first arm, raise second arm
2	Hands in front	- reach both arms in front together - drop one arm, drop second arm, reach first arm, reach second arm
3	Forward flexion	- bend forward from waist, weapon in front - return to neutral, repeat
4	Lateral bending	- bend sideways at waist with weapon resting on floor - return to neutral, repeat to opposite side
5	Rotation	- rotate at waist with weapon in front - return to neutral, repeat to opposite side
6	Canteen access	- remove canteen from pouch in standing position - return canteen to pouch, repeat
7	Respirator Access	- remove gas mask from respirator pouch in standing position - return mask to pouch, repeat
8	Sit down	- move from standing to seated position
9	Lie in prone position	- move from seated to prone position
10	Emergency doff	- return to standing position - emergency doff pack with available quick release system

Table 2.5. Description of battle order systems.

Symbol		Description[1]		Connection of Components
AW	–	webbing style with thin padded yoke, straps across back.	–	metal clips around belt with metal retainers at bottom.
	–	two magazines, butt pouch, canteen, utility pouch, bayonet.		
BW	–	webbing style with thin padded yoke, mesh across back.	–	rounded metal clips in material slots on belt.
	–	two magazines, butt pouch, utility pouch, canteen (in entrenchment tool component), bayonet.	–	straps and snaps around belt.
CW	–	webbing style with thicker padded yoke, full material back.	–	plastic tabs (top and bottom) in grommets on belt.
	–	two magazines, butt pouch, utility pouch, canteen, bayonet.	–	straps and velcro around belt.
LCV	–	front opening vest.	–	all pockets were rigidly attached.
	–	two lower front pockets, two upper front magazine pockets, two side pockets, two large back pockets (upper and lower), bayonet.		

[1] all battle orders used a standard format bayonet looped around belt.

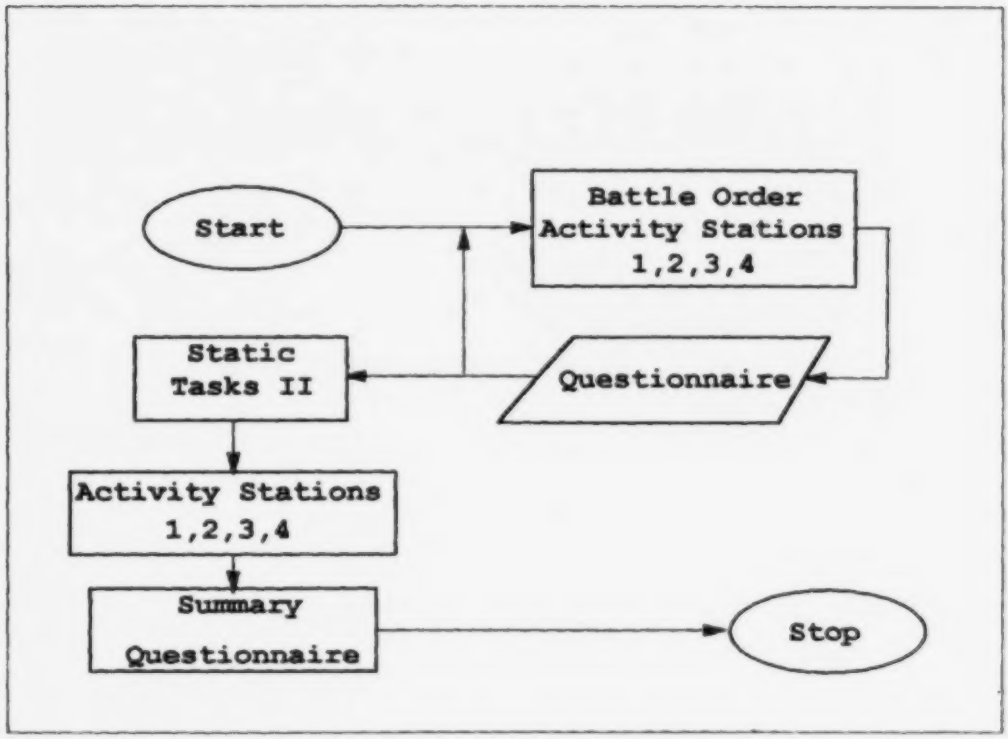


Figure 2.2 Path of battle order LCS trial.

Table 2.6 Description of battle order testing activity stations (AS).

Activity Station	Station Name	Description
1	Horizontal mouse hole	- 0.5 m X 0.5 m X 2.0 m long - subjects required to climb through tunnel w/ 90 degree bend at end
2	Vertical mouse hole	- 0.5 m X 0.5 m X 2.5 m height - subjects required to climb full height, exit, return to ground
3	Leopard crawl	- 6.0 m crawl under 0.5 m obstacles, w/ 180 degree turn
4	Over and under	- under 0.5 m barrier, over 1.2 m barrier, under 0.5 m barrier - repeat - barriers separated by 0.5 m

Table 2.7 Description of battle order static tasks test.

Task	Task Name	Description
1	Hands above head	- reach both arms above head together - drop one arm, drop second arm, raise first arm, raise second arm
2	Hands in front	- reach both arms in front together - drop one arm, drop second arm, reach first arm, reach second arm
3	Forward flexion	- bend forward from waist, weapon in front - return to neutral, repeat
4	Lateral bending	- bend sideways at waist with weapon resting on floor - return to neutral, repeat to opposite side
5	Rotation	- rotate at waist with weapon in front - return to neutral, repeat to opposite side
6	Canteen access	- remove canteen from pouch in standing position - return canteen to pouch, repeat
7	Respirator Access	- remove gas mask from respirator pouch in standing position - return mask to pouch, repeat
8	Sit down	- move from standing to seated position
9	Lie in prone position	- move from seated to prone position
10	Prone grenade toss	- toss mock grenade at 2 m X 1 m target 6 m away; repeat 3 X
11	Prone rifle fire	- sight rifle in prone position
12	Prone ammunition access	- remove mock magazine from pouch - return magazine to pouch, repeat
13	Prone canteen access	- remove canteen from pouch - return canteen to pouch, repeat
14	Prone respirator access	- remove gas mask from respirator pouch - return mask to pouch, repeat

3.0 FAST Trials Test Results

Four sets of questionnaire results were obtained from the FAST trials testing. **Base system testing**, similar to Section B, incorporated the results from all trials performed with five base systems (A,B,C,D,E), with in-service battle order and no fragmentation vest (NF). **Integration testing** provided a comparison between Canadian 1982 Pattern Webbing (W) and the current load carriage vest design (V) worn with the in-service Canadian system (C) and a prototype Canadian design (D). **Fragmentation vest testing** provides a comparison for the five base systems between results with and without the fragmentation vest. **Battle order testing**, which was performed in the second stage of each FAST trial, compared three webbing systems (AW, BW, CW) with one vest style battle order (LCV). In all cases, table values are averaged for all trials.

Subjects

Significant differences were seen between subject anthropometrics and data collected for the 1988 American military anthropometric survey (ANSUR) on the measurements of neck circumference, buttock circumference, biacromial breadth, and back length. While the back length difference is likely attributable to the derived nature of the back length measure from the ANSUR data (from sitting height, buttock depth, and head height), the other variables represent true group differences.

3.1 Base System Testing

A subject performing one marching order activity station (boulder hop) is shown in Figure 3.1-1; a static tasks test is shown in Figure 3.1-2. Table 3 1-1a shows the questionnaire results of the base system testing on marching order activity stations. Marching order activity station question responses were grouped into three categories, as defined in Table 3.1-1b. Static performance measures for marching order base systems are presented in Table 3.1-2, while results from the marching order activity station summary are included in Table 3.1-3. These summary reults were collected in combination with the base marching order system ratings of personal discomfort, which are presented in Table 3.1-4. The results of the overall summary for the base system marching orders, which was performed as part of a summary focus group following all testing, are presented in Table 3 1-5.

Figure 3.1-1. Boulder hop, one of five marching order activity stations in the FAST Trial

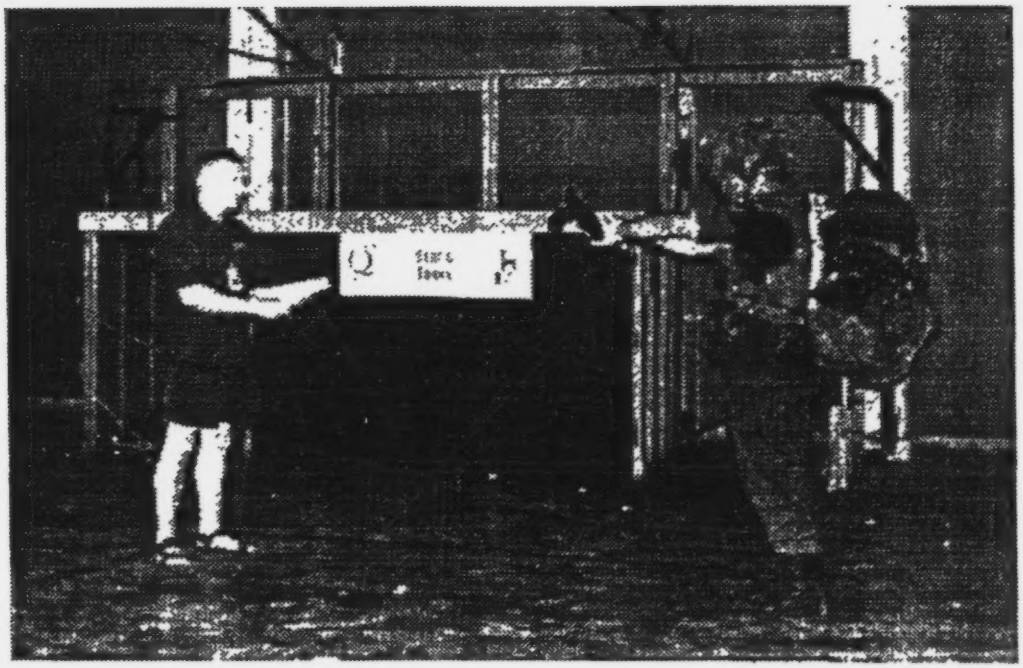


Figure 3.1-2. FAST Trials investigator leading subject through marching order static tasks test.

Table 3.1-1a. Subjective performance measures from FAST Trial marching order activity station responses.

Performance Variable	ANF	BNF	CWNF	DWNF	ENF
Balance	4.3	4.8	3.7	3.2	4.5
Load Control	4.7	5.3	3.6	3.5	4.5
Agility	4.6	5.3	4.1	3.3	4.7

Scores greater than 5 (box) were considered superior. Scores 3.5 or less (grey) were considered inferior.

Table 3.1-1b. Categories for combined averaging of marching order activity station question responses.

Performance Variable	Question Number	Station	Content
Balance	1	Boulder hop	- balance while jumping
	2	Bent balance beam	- balance while running
	3	Straight balance beam	- balance while running
Load Control	4	Agility run	- ability to change direction
	7	Forward ramp climb	- ability to get going
Agility	5	Fence climb	- ability to climb fence
	6	Side slope walk	- balance across slope

Table 3.1-2. Marching order static performance measures for base systems.

	ANF	BNF	CWNF	DWNF	ENF
Arms					
Hands above head	4.1	4.6	3.3	3.1	3.8
Hands in front	4.9	5.3	4.9	4.7	4.6
Trunk					
Forward flexion	5.1	4.9	3.9	4.7	4.4
Lateral bending	4.1	5.1	3.3	3.1	4.4
Trunk rotation	5.1	5.7	4.3	3.8	4.6
Total body					
Sit down	4.1	4.4	4.0	4.1	4.1
Lie in prone position	2.9	3.4	1.1	1.4	2.0
Accessibility					
Emergency doff	5.1	2.9	4.7	3.8	5.3
Canteen access	4.3	5.1	4.8	3.8	4.9
Respirator Access	5.1	5.6	5.2	4.9	5.0

Scores greater than 5 (box) were considered superior. Scores 3.5 or less (grey) were considered inferior.

Table 3.1-3. Marching order activity station summary ratings for base systems.

	ANF	BNF	CWNF	DWNF	ENF
Acceptability	4.1	5.5	3.1	2.9	4.0
Integration	3.6	4.8	2.7	2.6	4.1
Mobility	4.3	5.2	3.0	2.9	3.8
Physical comfort	4.1	4.5	2.4	2.4	3.1
Thermal comfort	4.8	5.0	3.0	3.2	4.0

Scores greater than 5 (box) were considered superior. Scores 3.5 or less (grey) were considered inferior

Table 3.1-4. Ratings of perceived discomfort for marching order testing of base systems.

	ANF		BNF		CWNF		DWNF		ENF	
Anterior										
Shoulders	6.3	(75)	5.0	(86)	8.9	(71)	10.2	(78)	7.2	(73)
Neck	4.8	(38)	0.3	(14)	0.3	(14)	5.9	(55)	0.5	(9)
Hips	0.0	(0)	0.0	(0)	0.0	(0)	0.0	(0)	1.1	(6)
Posterior										
Shoulders	5.5	(63)	4 3	(43)	7.1	(57)	7.3	(44)	1.7	(18)
Neck	2.3	(38)	0.6	(14)	3.6	(43)	1.0	(11)	2.5	(27)
Hips	0.6	(13)	0.0	(0)	1.6	(29)	1.3	(22)	2.6	(27)
Low back	6.5	(87)	1.7	(29)	3.7	(57)	6.0	(89)	2.1	(45)

Scores less than 2.5 (box) were considered superior. Scores greater than 6.5 (grey) were considered inferior. Percentage of subjects reporting some discomfort in area of interest while testing system is included in brackets

Table 3.1-5. Overall ratings for base systems.

	ANF	BNF	CWNF	DWNF	ENF
Balance	2.3	1.1	3.3	2.6	1.9
Comfort	2.0	1.1	3.7	2.7	2.1
Fit	2.0	1.3	3.6	2.7	1.8
Manoeuvrability	2.4	1.3	3.4	2.4	2.1

Scores of 1.9 or less (box) were considered superior. Scores 3.0 or above (grey) were considered inferior.

3.2 Integration Testing

Marching order activity station questionnaire results for integration comparisons are found in Table 3.2-1. Marching order activity station question responses were grouped into three categories, as previously defined in Table 3.1-1b. Table 3.2-2 contains static performance measures for marching order integrated systems. Marching order activity station testing summaries for these systems can be found in Table 3.2-3. Ratings of personal discomfort for the activity station testing of the integration marching orders are presented in Table 3.2-4. The results of the overall summary for the integrated testing marching orders, which was performed as part of the summary focus group, are presented in Table 3.2-5. Figure 3.2-1 shows a subject receiving an aural temperature measurement while testing system CVNF.

Table 3.2-1. Subjective performance measures from FAST Trial marching order activity station responses for systems during integration testing.

	CWNF	CVNF	DWNF	DVNF
Balance	3.7	3.7	3.2	3.5
Load Control	3.6	4.2	3.5	4.1
Agility	4.1	4.1	3.3	4.0

Scores greater than 5 (box) were considered superior. Scores 3.5 or less (grey) were considered inferior

Table 3.2-2. Marching order static performance measures for integrated systems.

	CWNF	CVNF	DWNF	DVNF
Arms				
Hands above head	3.3	3.1	3.1	3.0
Hands in front	4.9	3.9	4.7	4.5
Trunk				
Forward flexion	3.9	4.6	4.7	4.0
Lateral bending	3.3	4.3	3.1	3.3
Trunk rotation	4.3	4.3	3.8	4.2
Total body				
Sit down	4.0	4.6	4.1	3.5
Lie in prone position	1.1	2.5	1.4	1.2
Accessibility				
Emergency doff	4.7	5.5	3.8	3.2
Canteen access	4.8	4.4	3.8	2.4
Respirator Access	5.2	5.2	4.9	5.6

Scores greater than 5 (box) were considered superior. Scores 3.5 or less (grey) were considered inferior.

Table 3.2-3. Marching order activity station summary ratings for integrated systems.

	CWNF	CVNF	DWNF	DVNF
Acceptability	3.1	3.4	2.9	3.5
Integration	2.7	3.4	2.6	3.2
Mobility	3.0	3.0	2.9	3.2
Physical comfort	2.4	3.0	2.4	3.2
Thermal comfort	3.0	3.4	3.2	2.3

Scores greater than 5 (box) were considered superior. Scores 3.5 or less (grey) were considered inferior.

Table 3.2-4. Ratings of perceived discomfort for marching order testing of integrated systems.

	CWNF		CVNF		DWNF		DVNF	
Anterior								
Shoulders	8.9	(71)	12.4	(100)	10.2	(78)	8.7	(100)
Neck	0.3	(14)	2.5	(25)	5.9	(55)	0.0	(0)
Hips	0.0	(0)	1.0	(13)	0.0	(0)	0.0	(0)
Posterior								
Shoulders	7.1	(57)	9.0	(88)	7.3	(44)	6.7	(83)
Neck	3.6	(43)	2.0	(38)	1.0	(11)	0.8	(17)
Hips	1.6	(29)	0.0	(0)	1.3	(22)	0.0	(0)
Low back	3.7	(57)	5.0	(63)	6.0	(89)	2.0	(33)

Scores less than 2.5 (box) were considered superior. Scores greater than 6.5 (grey) were considered inferior Percentage of subjects reporting some discomfort in area of interest while testing system is included in brackets

Table 3.2-5. Overall ratings for integrated systems.

	CWNF	CVNF	DWNF	DVNF
Balance	3.3	2.1	2.6	3.0
Comfort	3.7	2.3	2.7	3.3
Fit	3.6	2.4	2.7	3.0
Manoeuvrability	3.4	2.5	2.4	3.0

Scores of 1.9 or less (box) were considered superior Scores 3.0 or above (grey) were considered inferior.

Figure 3.2 - 1. Subject in CVNF receiving aural temperature measurement.

3.3 Fragmentation Vest Testing

Comparisons between marching order systems with (F)and without (NF) fragmentation vests are presented in this section as the difference in averaged questionnaire responses (F-NF). In this way, table values which are positive show an improvement with the incorporation of the fragmentation vest and the marching order. Figure 3.3-1 shows a subject completing the battle order static tasks testing in the test fragmentation vest. Table 3.3-1 contains marching order activity station questionnaire results for fragmentation vest testing Marching order activity station question responses were grouped into three categories, as previously defined in Table 3.1-1b. Comparisons of marching order systems with and without fragmentation vest for static performance measures are found in Table 3.3-2. Marching order activity station testing summaries comparing these systems with and without fragmentation vests can be found in Table 3.3-3. Ratings of personal discomfort for the activity station testing of marching order systems with and without fragmentation vest are presented in Table 3.3-4. The results of the overall summary for all marching orders with fragmentation vest are presented in Table 3.3-5. Physiological differences, for marching order testing, are included in Table 3.3-6.

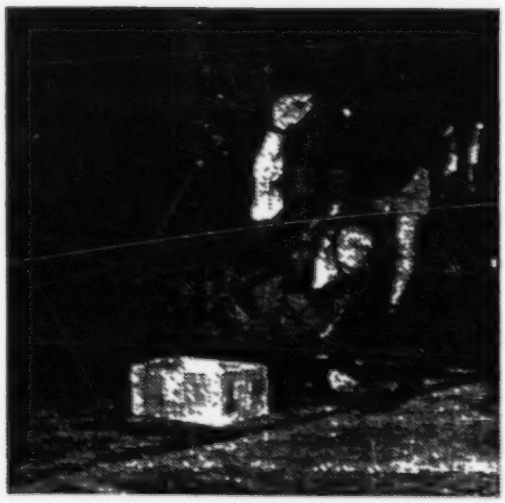


Figure 3.3-1. Battle order testing of fragmentation vests.

Table 3.3-1. Subjective performance measures from FAST Trial marching order activity station responses.

	AF-ANF	BF-BNF	CWF-CWNF	DWF-DWNF	EF-ENF
Balance	0.4	-0.6	0.3	0.3	-0 2
Load Control	-0.2	-0.9	0.9	0.6	0.1
Agility	0.2	-1.1	0.4	0.6	-0.2

Differences greater than 0.5(box) were considered to indicate that the fragmentation condition (F) was superior. Negative differences larger than -0.5 (grey) were considered to indicate superior performance of the no fragmentation (NF) condition.

Table 3.3-2. Marching order static performance measures for fragmentation testing.

	AF-ANF	BF-BNF	CWF-CWNF	DWF-DWNF	EF-ENF
Arms					
Hands above head	-1.2	-1.6	-0.5	-0.5	-1.0
Hands in front	-0.6	-1.5	-1.3	-0.6	0.4
Trunk					
Forward flexion	-0.3	-0.2	0.6	-0.6	0.4
Lateral bending	0.3	-1.1	0.6	0.6	0.2
Trunk rotation	-0.2	-1.1	0.6	0.5	0.2
Total body					
Sit down	-0.6	-1.1	0.5	-0.8	0.9
Lie in prone position	-1.0	-1.2	0.7	0.2	0.4
Accessibility					
Emergency doff	-2.2	0.3	0.4	-0.1	0.7
Canteen access	-0.5	-0.6	-0.4	0.8	0.1
Respirator Access	0.6	-0.5	0.1	0.2	0.0

Differences greater than 0.5(box) were considered to indicate that the fragmentation condition (F) was superior. Negative differences larger than -0.5 (grey) were considered to indicate superior performance of the no fragmentation (NF) condition.

Table 3.3-3. Marching order activity station summary ratings for fragmentation testing.

	AF-ANF	BF-BNF	CWF-CWNF	DWF-DWNF	EF-ENF
Acceptability	0.2	-1.2	0.0	0.1	0.6
Integration	-0.1	-1.2	0.4	0.8	-0.3
Mobility	-0.4	-1.7	-0.1	0.8	0.4
Physical comfort	-0.5	-1.2	0.2	0.3	0.3
Thermal comfort	-1.7	-2.5	-0.2	-0.1	-1.4

Differences greater than 0.5(box) were considered to indicate that the fragmentation condition (F) was superior. Negative differences larger than -0.5 (grey) were considered to indicate superior performance of the no fragmentation (NF) condition.

Table 3.3-4. Ratings of perceived discomfort for marching order testing of fragmentation base systems.

	AF		BF		CWF		DWF		EF	
Anterior										
Shoulders	6.9	(75)	9.3	(67)	15.3	(88)	12.6	(100)	4.0	(60)
Neck	1.4	(38)	1.0	(11)	0.0	(0)	1.7	(29)	0.0	(0)
Hips	0.0	(0)	0.0	(0)	1.5	(25)	0.0	(0)	1.2	(20)
Posterior										
Shoulders	3.0	(25)	2.6	(22)	7.3	(50)	6.0	(57)	2.4	(40)
Neck	1.0	(13)	2.3	(11)	3.5	(63)	0.0	(0)	0.0	(0)
Hips	1.3	(25)	0.7	(11)	0.0	(0)	0.6	(14)	1.6	(20)
Low back	0.0	(0)	2.6	(44)	7.4	(88)	5.1	(86)	1 2	(20)

Scores less than 2.5 (box) were considered superior. Scores greater than 6.5 (grey) were considered inferior. Percentage of subjects reporting some discomfort in area of interest while testing system is included in brackets.

Table 3.3-5. Overall ratings for fragmentation systems.

	AF	BF	CWF	DWF	EF
Balance	2.0	1.8	3.1	3.0	2.0
Comfort	2 3	1.8	3.3	2.7	2.2
Fit	2.4	1.8	3.3	3.0	2.2
Manoeuvrability	2.4	1.9	3.0	3.0	1 8

Scores of 1.9 or less (box) were considered superior. Scores 3.0 or above (grey) were considered inferior.

Table 3.3-6. Physiological responses to marching order testing of fragmentation systems.

	F	NF	Significant Difference
Mean Surface Temperature			
Trial average	33.95	33.48	*
Trial average change (start to finish)	0.45	-0.11	*
Subject Heart Rate			
Trial average	147.11	145 77	
Trial average change (start to finish)	19.11	19.66	

All averages are for 56 trials (n=56). Signficance values established on paired t-test within subjects, t (0.05, 27).

3.4 Battle Order Testing

Comparison results from the battle order activity station questionnaires for the four systems (AW, BW, CW, LCV) tested are available in Table 3.4-1. For each system, results for frag and no frag conditions are lumped. Static task results for the battle order testing are found in Table 3.4-2. Figure 3.4-1 is a photograph of one static test for battle order. Summary results for the battle order testing of these four systems can be found in Table 3.4-3, with discomfort ratings available in Table 3.4-4.

Figure 3.4-1. Prone rifle firing test of LCV battle order.

Table 3.4-1. Battle order activity station responses for test systems.

	AW	BW	CW	LCV
Horizontal Mouse Hole				
Entry	3.3	4.7	3.0	4.6
Exit	3.8	4.0	3.1	3.8
Vertical Mouse Hole				
Climbing	3.8	5.0	3.1	4.7
Exit	3.6	5.0	3.0	4.7
Leopard Crawl				
Comfort	4.3	4.9	3.5	5.1
Agility	4.4	5.0	3.4	5.1
Over and Under				
Crawl	4.6	5.1	3.8	4.9
Agility	4.5	4.9	3.7	4.9

Scores greater than 5(box) were considered superior. Scores 3.5 or less (grey) were considered inferior

Table 3.4-2. Battle order static task responses for test systems

	AW	BW	CW	LCV
Arms				
Hands above head	5.6	5.9	5.6	5.4
Hands in front	5.8	5.9	5.7	5.8
Trunk				
Forward flexion	5.3	5.6	4.8	5.8
Lateral bending	5.0	5.4	4.6	5.5
Trunk rotation	5.5	5.7	5 2	5.8
Total Body				
Sit down	5.1	5.4	5.2	5.8
Lie in prone position	5.3	5.6	4.8	5.8
Prone grenade toss	5.1	5.4	5.3	5.2
Prone rifle fire	5.3	5.4	4.9	5.7
Prone ammunition access	4.3	5 6	4.7	5.4
Canteen access	4.4	5.0	4.8	3.6
Respirator access	4.8	5.3	5.3	5.4

Scores greater than 5 (box) were considered superior. Scores 3.5 or less (grey) were considered inferior.

Table 3.4-3. Battle order testing summary results for test systems.

	AW	BW	CW	LCV
Acceptability	4.3	5.1	4.1	5.1
Durability	4.9	5.1	3.4	4.9
Mobility	4.8	5.0	4.1	5.1
Physical Comfort	4.4	5.3	3.8	4.9
Thermal Comfort	4.5	5.1	4.3	3.8

Scores greater than 5 (box) were considered superior. Scores 3.5 or less (grey) were considered inferior.

Table 3.4-4. Ratings of perceived discomfort for test systems in battle order testing summary.

	AW		BW		CW		LCV	
Anterior Regions								
Shoulder	0.3	(13)	0.0	(0)	0.5	(11)	3.5	(57)
Neck	0.0	(0)	0.0	(0)	0.0	(0)	0.0	(0)
Hips	3.6	(25)	3.3	(43)	5.4	(59)	0.0	(0)
Thermal	0.0	(0)	0.0	(0)	0.0	(0)	0.5	(7)
Posterior Regions								
Shoulders	0.5	(13)	0.0	(0)	0.3	(7)	1.2	(29)
Neck	1.1	(13)	0.0	(0)	0.0	(0)	0.0	(0)
Hips	1.3	(25)	0.9	(11)	2.4	(30)	0.0	(0)
Low back	1.1	(25)	0.3	(11)	0.8	(15)	0.5	(7)
Thermal	0.0	(0)	2.1	(33)	0.0	(0)	0.5	(7)

Scores less than 2.5 (box) were considered superior. Scores greater than 6.5 (grey) were considered inferior. Percentage of subjects reporting some discomfort in area of interest while testing system is included in brackets.

4.0 FAST Trials Test Discussion

Discussion of FAST Trials results available in this section is divided into two parts. Main findings, highlighting superior and inferior results, will be provided for each subsection of Section 3. Conclusions relating these results to load carriage system design features will be provided following each subsection.

4.1 Base System Testing

4.1.1 Main Findings

Marching order activity station responses (Table 3.1-1a) showed that BNF was superior in load control and agility performance. Inferior scores were received by DWNF in all aspects of balance, load control, and agility testing. Static task testing (Table 3.1-2) revealed that all base systems were inferior for lying in a prone position. BNF was also inferior in emergency doffing, while ANF and ENF were scored as superior for this static task. CWNF and DWNF had inferior performance in placing hands above head and lateral bending, while ANF was superior in forward flexion and trunk rotation. BNF was superior in positioning the hands in front, lateral bending, and in trunk rotation. All systems had adequate to superior performance in the sit down, standing canteen access, and standing respirator access static tasks. Table 3.1-3 shows that CWNF and DWNF had inferior scores for all aspects of acceptability, integration, mobility, physical comfort, and thermal comfort on the marching order activity station summary questionnaire. System ENF was inferior for physical comfort testing. BNF was found to be superior in terms of system acceptability, mobility, and thermal comfort. Discomfort ratings results for the base systems showed that all systems had a discomfort rating which exceeded 5.0 (Moderate to High Discomfort) in the front shoulder region, with over 70 % of subjects reporting some discomfort in this region for all test systems. CWNF and DWNF also had excessive discomfort scores in the posterior shoulder region. All base systems were good to superior in the remaining anatomical areas, except for ANF, which was high in discomfort (6.5) in the low back area, and DWNF, which had high discomfort scores for the low back and anterior neck regions. The overall summary for the base systems (Table 3.1-5) shows that BNF had superior ratings in all aspects of balance, comfort, fit, and manoeuvrability, while CWNF was rated as inferior in all final summary categories. ENF was found to be superior in terms of balance and fit.

4.1 2 Conclusions

The soft internal frame and short length of the BNF system made it most acceptable to the subjects for the marching order activity stations. With the small pack high on the back and close to the body, the moment of inertia of the torso/pack complex is much smaller and therefore it is easier to control the upper body during activities. Conversely, DWNF had a very stiff external frame which did not allow subjects to cinch the load into close contact with the posterior shoulders. Subsequently, this system scored poorly on the activity stations because of subject difficulty in controlling the motion. A poor shoulder suspension system contributed to this difficulty.

The length of systems CWNF and DWNF caused difficulty in static tasks testing of lateral bending. Low scores, approaching inferiority, were also seen for these systems, with the addition of ENF, for forward flexion and trunk rotation. The combination of straps for webbing and LCS made extension of the hands above the head or out in front difficult with these three systems. Subjects reported that the thickness of the webbing straps created this restriction, which was not as evident in ANF and BNF, which had thinner webbing yoke straps No systems were acceptable for lying prone, as they all restricted motion of the helmeted head. BNF was ranked as inferior for emergency doffing, due to the absence of any system to perform this action. The low score attributed to DWNF for the doff task was due to the loss of the sternum strap with each doff. Subjects preferred a two step doff procedure (chest strap, one shoulder strap), as evidenced by the high score for ANF. Familiarity with the doff and post-doff techniques (prone emergency positioning behind pack) for ENF led to high scores from the subjects. Access to respirator and canteen were adequate to superior for all systems, indicating good functional use of the hands at the waist level during load carriage.

The high incidence and level of discomfort ratings found for all base systems in the shoulder region indicates that proper load sharing between the shoulders and hips of the wearer is not being acheived. Poorly designed hip belts, incapable of supporting any vertical load, are the primary cause of this. Systems which did have padded hip belts (ANF and DWNF) were improperly used by most subjects, who were unfamiliar with the benefits of load sharing. High discomfort scores were also reported in the anterior neck area for these two systems. The sternum strap, a feature of only these

two packs, provided a medial angle on the shoulder straps which increased compresison in this clavicle region. High discomfort scores in the posterior region for systems CWNF and DWNF were attributed to integration problems, leading to increased contact pressure, between the thick webbing yoke and the LCS suspension. The open upper back area in the frame of ENF prevented this system from having the same problem. Discomfort reported for the low back area, most noticably in ANF, was directly attributable to the overall length of the LCS.

Inferior scores in all marching order system summary questions were recorded for CWNF and DWNF. These values represent general subject dissatisifaction with equipment they were already familiar, and unhappy, with (CWNF) or which they felt was largely unsuitable for military use (DWNF). Physical comfort with the ENF system was also ranked as inferior, which does not correspond with other results from this testing. This anomaly indicates that subject bias due to past experience with the system has been included in responses to the question. The reverse of these results can be seen in the scores for BNF, which were superior or near superior in all five categories. Strong support was received for this system from all subjects, with comments highlighting the increased mobility possible with the internal frame and the small pack size. Thermal comfort was also increased with the short length, which allowed for increased heat dissipation in the lower back area. Focus group testing revealed that subjects had experience with the system due to joint mission work with military currently using the pack.

Overall ratings for the base systems, which were performed after each subject group had completed four trials, echoed these results. BNF had superior scores for all aspects, while CWNF was rated as inferior on all counts. Again, strong dislike for the CWNF system, based on previous experience, is evidenced in these results.

4.2 Integration Testing

4.2.1 Main Findings

Improvements in all aspects of the marching order activity station questionnaires were seen for system D with the addition of the load carriage vest (LCV). These increases led to significantly higher scores for DVNF in load control and agility questions. Load control scores were also increased for system C with the use of LCV battle order. Static task testing did not show the same general improvement with the incorporation of the LCV. Mostly decreased subjective scores, noticable in the sit down, lie in prone position, emergency doff, and canteen access static tasks, were seen for system D when the LCV was added. Improvement was seen in all marching order summary station responses with the integration of the LCV into both LCS, with the exception of the thermal comfort of D. Improvement was not sufficient to lift any of the scores above the inferior level. Table 3.2-4 shows that discomfort was decreased in all areas with the integration of the LCV and system D. System C showed larger discomfort scores with the integration of the LCV, with the exceptions of the posterior neck and hips region. For both systems, discomfort scores were not reduced to satisfactory levels in areas where the score was inferior with the webbing battle order. Summary ratings (Table 3.2-5) showed that integration of the LCV with system C reduced scores in all four overall summary categories to an acceptable level. The opposite phenomenon was seen for system D, where all LCV summary scores were significantly worse.

4.2.2 Conclusions

Results of integration testing revealed that the LCV was a slight improvement over the webbing battle order when integrated with system C, most noticeably in the overall summary. Improved marching order summary scores and overall summary scores, as well as improved load control scores for the agility stations, were reported by the subjects for system CVNF. Lower scores in arm based static tasks were seen for CVNF, as expected due to the arm restricition imposed by the large volume of material in the shoulder section of the LCV. A lower score was also seen for canteen access, a function of the lack of a dedicated pocket for the canteen in the LCV, and the subsequent sliding of the canteen to a posterior position in the large lateral waist pocket. While discomfort scores were higher for CVNF in most anatomical areas, this result was not reflected in the summary questionnaires.

Improvement in system integration for D with the addition of the LCV was more questionable. Small improvements were seen in some areas, such as the marching order summary questionnaire and the reported discomfort scores, when the LCV was added. However, the overall summary scores across all dimensions were decreased in value with the addition of the LCV to system D.

4.3 Fragmentation Vest Testing

4.3.1 Main Findings

Marching order activity station questionnaires showed a significant reduction, for system B only, in all categories with the addition of the fragmentation vest. Significant improvements in score for the load control and agility questions for system D, and the load control category for system C, were seen with the incorporation of the fragmentation vest. Static tasks testing of marching order (Table 3.3-2) showed a variable effect with the addition of the fragmentation vest to the load carriage complex. Decreased performance with the frag was noted for all systems in tests featuring arm motion (hands above head, hands in front)while increased scores were seen for system C with addition of the frag to the trunk and total body based tests. System B showed decreased performance for all static tests, with the exception of the emergency doff, when the fragmentation vest was added. System A also experienced all decreased scores when the frag was added, with the exception of the respirator access. System D had significantly improved scores for lateral bending, trunk rotation, and canteen access when the frag vest was included, but also had signifcantly dcreased scores for forward flexion and sit down in this configuration. Scores for emergency doff and sit down were signifcantly improved with the addition of the frag vest to system E. Summary ratings from the marching order activity stations showed an significant increase in ratings for DWF on the integration and mobility questions, while BF had significantly decreased scores for all questions. AF and EF were also scored significantly lower, on physical and thermal comfort, and thermal comfort respectively. EF scored significantly higher on accpetability. Discomfort ratings for all systems, with the exception of EF, were above acceptable for the anterior shoulder region with the addition of the fragmentation vest. CWF also received inferior scores for the posterior shoulder and low back regions. In overall ratings, CWF was inferior in all categories while DWF was inferior in balance, fit, and manoeuvrability. BF was found to be superior in all categories, while EF ranked as superior for manoeuvrability. Physiological data showed a significantly increased mean temperature and change in temperature for trials with fragmentation vest, grouped across load carriage system type.

4.3.2 Conclusions

The introduction of the fragmentation vest, with its space filling bulk, provided for improved load control and agility in external frame systems. This increased contact between the packs (C, D) and the frag vest allowed the torso of the subject and the pack to move more easily as one unit. Conversely, internal frame systems which had previously scored well, most notably B, had decreased scores with the incorporation of the frag vest because the pack could not be drawn in to the body as closely.

The added bulk of the frag vest did decrease scores for static tasks involving the arms, as the combination of material from fragmentation vest and the LCS suspension provided a greater restriction on shoulder motion. The increased load control of the external frame systems with the frag vest was again seen in the higher results for CWF in the trunk and total body focused tests. The absence of the ammunition pouches, which reduced subject motion by conflicting between the torso and the leg sections as the trunk angle decreased, also helped to increase the scores for systems C and D. Systems B and A again showed decreased scores when the frag vest was added because the pack/torso combination was less uniform.

In marching order summary ratings, BF received lower scores than BNF, further indication that the combination of internal frame pack and frag vest was less acceptable than internal frame pack alone. Systems which scored well without the frag vest (A, E) showed lower acceptance scores in physical and thermal comfort when the frag vest was added.

Despite the negative impact of the fragmentation vest, BF was still scored as superior on all accounts in the overall summary, indicating subject satisfaction with this system in both frag and no frag configurations. While summary scores were higher, indicating less acceptability, for systems A, B, and E with frag vest, scores for C and D with frag were not significantly lower.

The thermal impact of the frag vest was signficant when the systems were grouped, as higher mean temperatures and changes in temperature were seen for testing with the frag vest. However, only systems A and E showed signficantly lower thermal comfort scores in the frag condition on the summary questionnaire.

4.4 Battle Order Testing

4.4.1 Main Findings

Battle order activity station responses revealed inferior scores received by CW for the horizontal mouse hole, vertical mouse hole, and leopard crawl. An inferior score was also received by AW for entry into the horizontal mouse hole. Superior scores were received by the LCV for both aspects of the leopard crawl (comfort, agility) and by the BW for both aspects of the vertical mouse hole (climbing, exit), as well as the agility question in leopard crawl and the crawl question in the over and under obstacle. Static tasks testing provided superior or acceptable scores for all testsw in all battle orders. The only score below 4.0 was received on the canteen access test by the LCV. Similarly, only one inferior scores was seen in the battle order summary results; this was for CW in terms of durability. Superior scores on all questions were received by BW, while the LCV received superior scores for accpetability and mobility. There were no areas rated as inferior in comfort for the battle order testing. Scores in the acceptable range were received by all three webbing systems in the anterior hips region and in the anterior shoulder region for the LCV; all other scores were superior.

4.4.2 Conclusions

Battle order systems with a reduced profile (BW, LCV) scored highly on battle order activity stations. Bulk in the front and rear waist areas, as seen in systems AW and CW, caused low scores, particularly on the mousehole activities. Subject dissatisfaction was highest with system CW, based both on familiarity and poor design, particularly of closures and connections between webbing items and webbing belt. The inferior score for CW in the durability question of the summary, and the failure of some connections during the testing, emphasize this result. A low canteen access score for LCV was again indicative of the lack of dedicated pocket in this system for this item. Subjects found it impossible to keep the canteen in a comfortable position, and also found it difficult to operate pocket snaps without a solid backing, which was not present when the canteen fell into a horizontal position. The high overall acceptance of BW was attributed by the subjects to the thin shoulder strapping and the use of mesh in the yoke.

5.0 Conclusions and Recommendations

1. Shoulder discomfort was rated as high by users of all base systems during testing. However, shoulder discomfort did not appear to negatively effect the overall comfort ratings of LCS.

2. System B had superior performance scores, reflecting the effect of a smaller pack located high on the back. The absence of an emergency doff mechanism was the major negative feature subjects reported for this system.

3. The importance of marching/battle order integration was demonstrated by the differences in score for similar marching order systems with differing battle orders (ex. CWNF, CVNF) It is essential that LCS be designed with consideration of the interaction between components.

4. Significantly increased temperature effects were seen with the incorporation of a fragmentation vest to the LCS during testing. Similar effects were not seen with heart rate.

5. Performance measures improved for most systems with the introduction of the fragmentation vest, due to the increased distribution of contact forces and the reduced counter-motion of the pack during the AS. The noticeable exception to this improvement was System B, which received lower mobility and physical comfort scores in this configuration.

6. LCV was a slight improvement on the current webbing style battle orders used with systems C and D. The reduced profile was favourable for agility and geometric exclusion activities in battle order only. The durability was also seen as an improvement.

7. Traditional webbing style battle orders were associated with discomfort on the thighs and hips due to contact between user and kit, especially during high mobility activities. Conversely, shoulder discomfort was increased in systems C and D with the addition of the LCV.

6.0 References

Balogun, JA., Robertson, RJ., Goss, FL., Edwards, MA., Cox, RC., and KF. Metz. (1986). Metabolic and perceptual responses while carrying external loads on the head and by yoke *Ergonomics*, **29(12)**: 1623-1635.

Borg, G. (1970). Perceived exertion as an indicator of somatic stress. *Scandinavian Journal of Rehabilitation Medicine*. **2(3)**: 92-98.

Datta, SR., and NL. Ramanathan. (1971). Ergonomics comparison of seven modes of carryin gloads on the horizontal plane. *Ergonomics*, **14(2)**: 269-278.

Holewijn, M. (1990). Physiological strain due to load carrying. *European Journal of Applied Physiology*, **59(4)**: 237-245.

Holewijn, M., and WA. Lotens. (1992). The influence of backpack design on physical performance. *Ergonomics*, **35(2)**: 149-157.

Legg, SJ., and A. Mahanty. (1985). Comparison of five modes of carrying a load close to the trunk. *Ergonomics*, **28(12)**: 1653-1660.

Renbourn, ET. (1954). The knapsack and pack. *Journal of the Royal Army Medical Corps*, **99(5)**. 1-200.

Stevenson, JM., Bryant, JT., dePencier, RD., Pelot, RP., and JG. Reid. *Research and Development of an Advanced Personal Load Carriage System*. **DCIEM Report No. 95-W7711-4-7225**, (1995).

Winsmann, FR., and RF. Goldman. (1976). Methods for evaluation of load-carriage systems. *Perceptual and Motor Skills*, **43**: 1211-1218.

Analysis of Seven Pack-Based Systems Using Human FAST Trials

Annex C.1

FAST Trials Subject Questionnaires

CONSENT FORM

FAST Trials Testing of Load Carriage Systems

This project has two aims : (1) to analyse the performance of different load carriage systems during typical military activities; and (2) to evaluate the penalty of wearing a fragmentation vest. Aspects of agility, fit, comfort, and integration with current military equipment, along with physiological and biomechanical parameters, will be researched.

The total test will take place over three days in half day blocks of time. The first session is for the collection of human factors data. A number of anthropometric measures will be collected from all subjects, and the appropriate sizes of kit will be identified for the following test stages.

During the four physical test stages you will be required to complete an activity circuit while wearing one of a possible seven load carriage systems currently used by, or proposed for use by, military forces. This activity circuit will incorporate five short stations with a 1000 m march between each station. Activities will be performed at a submaximal rate so that subjects can focus on the effect of the load carriage on their motion and comfort. Subjects will be asked to complete subjective questionnaires following each station. Subjects will then doff their marching order and complete eight short stations in battle order. These stations will allow you to focus on specific features such as balance, agility, comfort, and fit.

The final stage of testing will be a debriefing session after each system has been worn. At this station you will be asked to describe the features you like or dislike about each marching and battle order.

During the pack assessment phases of data acquisition, the subject will be asked to provide subjective feedback by means of questionnaires. Objective measures will also be taken from video and photographs of standing and walking postures, strap force sensors, skin temperature, body core temperature, and heart rate.

Core temperature will be measured by means of an infrared tympanic thermometer. This procedure is used in most hospitals and does not involve any hazard to the subject. Skin temperature will be measured with five skin surface thermistors. Application of these thermistors will require subjects to shave 2.5cm x 2.5 cm areas for attachment on their upper right chest, right forearm, back of their left hand, upper right thigh, and inner right shin. Porous surgical tape will be used for attaching thermistors and leads to subjects. While some sensitivity or itchiness could result from the combination of shaving and tape, it is highly unlikely that subjects will experience any discomfort. The heart rate reading will be taken using a monitor strapped around the chest and a wrist watch receiver.

All of the tasks have been selected based on typical military duties. Although events are timed, this is for synchronization purposes only. The core temperature measures and heart rate measures will be used to monitor any signs of cardiovascular stress. If heart rate exceeds the American College of Sports Medicine Guidelines or core temperature exceeds 39 °C, the test will be stopped. Because of the nature of the physical exertion while wearing a load carriage system, there is the potential for heat stress, high blood pressure, heart attack, or other cardiac arrhythmias. If you feel any other stressors during a testing station you may terminate the session without coercion to continue or other repercussions. If you are dissatisfied with the study or your treatment, you may contact the project coordinator, Dr. Joan Stevenson at Queen's University, Kingston ((613)545-6288). All information is confidential to Queen's and anonymity will be preserved.

I have read and understand the explanation of the procedure of this project, and I willingly agree to participate in the outlined experimental study.

Subject : _____ Date : _____

Witness : _____ Date : _____

Personal Information	
Name	
Rank	
Gender	
Age	years
Years of Military Service	years
Military Occupation / Trade	
Anthropometric Data	
Standing Height	in
Weight	lbs
Neck Circumference	cm
Chest Circumference	cm
Waist Circumference (Omphalion)	cm
Buttock Circumference	cm
Biacromial Breadth	cm
Waist Back Length (Omphalion)	cm
Fragmentation Vest Size	
Subject Number	
Test Systems	1 : _____ 2 : _____ 3 : _____ 4 : _____

External-Frame Pack

How to fit it

Load the pack, ensuring that the hipbelt fits right, then adjust the shoulder straps. Getting those two systems working in harmony solves 90 percent of pack-fitting complaints. From there, you can fine-tune load-lifter straps, belt stabilizers, and the rest.

1) The hipbelt should rest on your hip bones. The padded section of the belt should wrap around your hips but not quite meet in front. You may have to move the belt up or down on the frame so the pack's lower crossbar doesn't contact your back.

2) The shoulder straps. With most frame packs, the shoulder straps' upper anchor points should be even with the crest of your shoulders. The straps should be set wide enough apart so they don't pinch your neck, but narrow enough so they don't slide off to the side. If the straps are mounted too high, they'll transfer weight to the front of your shoulders and "wedge" you in place. Set too low, they'll take too much of the load, won't let the waistbelt share the burden, and tend to let the pack sway.

3) The load-lifters. Shoulder straps equipped with load-lifters generally should join the frame just below your shoulder crest. The load lifters themselves should join the frame at ear level and attach to the shoulder straps just forward of your collarbone. Tightening the load-lifters transfers more weight onto your shoulders. Loosening them will settle more weight onto your hips. You can vary the load-lifters' tension while you're on the move to help ease the burden when you've packed too much stuff.

4) Frame size. You can tell the frame is too small when you run out of headroom, can't get the shoulder straps and waistbelt far enough apart, or you can't let out the shoulder straps enough. It's too big when the top flops around or the shoulder straps bottom out against their adjustment buckles.

How to load it

Make these four simple steps a routine when packing:

1) Heaviest gear goes on top. Carry weight too low or too far back and you'll have to lean forward to counterbalance it all, which may turn you into a hunchback before your trip is over. Weighty stuff—stove, cook kit, bulk foods, stormgear, water bottles—goes in the upper compartment and top side pockets. Keep the heaviest items close to your back. Store fuel bottles and water bottles upright in separate pockets to avoid contaminating food or clothes. The tent, usually the heaviest item carried, is lashed on top behind the extender bar. Odd-shaped cargo fits under the top lid.

2) Midweight gear fills the middle. Stow clothing, personal gear, headlamps, maps, compass, compact camera, and the like into the center compartment and lower side pockets. Stuff spare clothing into a plastic bag for good storm insurance. Organize similar gear in separate pockets.

3) Light, bulky equipment goes toward the back of the pack. Lash your sleeping bag below the main pack bag. Always line its stuffsack with a plastic bag; after hiking all day in the rain, you'll be glad you did. Or carry the sleeping bag in a daypack you can use on side trips.

4) Lash long items to the frame. Tie your flyrod case and long tent poles to the sides of the frame, or shove them into tunnels behind the side pockets. An ice ax will fit into the pack bag's loop carrier.

Internal-Frame Pack

How to fit it

Start by stuffing the pack full and ensuring that all straps are loose. From here, it's a matter of putting it on so you can check for a comfortable fit.

1) Fit the frame. Slip into the shoulder straps and fasten the hipbelt where it's most comfortable—generally centered over your hip bones. Watch your profile in a mirror to see if the framesheet or stays protrude 2 to 4 inches above your shoulders; if less than that, look for a larger size. Longer stays can restrict headroom even though the suspension fits.

2) Fit the waist. The padded ends of the hipbelt shouldn't quite meet in front. Make sure there's enough room to change layers of clothing. If the unpadded part rubs your tummy, guess what? Gotta find a bigger hipbelt. Overtightening the hip stabilizer straps can distort the belt shape and fit.

3) Fit the shoulders. Shoulder straps should curve over your back and join the pack roughly 2 inches below your shoulder crests. Reposition the shoulder harness if necessary. Cinch shoulder straps so the lower ends are about a hand's width below your armpit. If they bottom out or come up short, find a different size pack or parts.

4) Fiddle with the load-lifters. These divert pressure to the front of your shoulders. The upper ends should join the frame at ear level. If you can't position them above shoulder height, find a larger frame. It's important that the buckle attaching the load-lifter to the shoulder strap be positioned just in front of your collarbone. Tighten the load-lifters to shift weight onto your shoulders, and loosen to shift the load to your waist. Vary them on the trail to give your back a break.

5) Fiddle with the other doodads. By now, a bit of fine-tuning should be all you need to achieve the ideal fit. Cinch the various hipbelt and/or pack-bag stabilizers to pull everything snug against your waist, but don't distort the smooth wrap of the belt. A sternum strap should be set a couple of inches below collarbone height. If the frame stays are shaped properly, the pack will comfortably hug your back.

6) Reshaping the frame. Shaping the frame stays remains a black art. Most frames come prebent to comfortably fit the majority of users. If you aren't among that privileged majority, we recommend working with a skilled packfitter, especially if the pack has a framesheet. But the merits of bending your own shouldn't be slighted: just keep a tracing of the original profile.

How to load it

An internal's cargo creates part of its load-bearing structure. Once filled, the pack stands tall, but with contents removed, it becomes a heap.

Merely filling the pack, however, isn't enough. You need to think carefully about the order in which your gear nestles into the pack. For level hiking over easy terrain, try to create a high center of gravity. Place loose clothing and other high-bulk low-weight items low in the gear department, gradually adding heavier, denser items on top (food, stove, water bottles). For more active pursuits like bushwhacking, skiing, or climbing, keep the dense stuff lower and closer to your back to retain a compact center of gravity. Many women, because of their naturally lower center of gravity, prefer the latter packing technique for all occasions.

How to put it on

Once loaded, there are several ways to put your pack on without pulling your back out.

1) Set it on a boulder, stump, or downed tree, slide your arms into the straps, then lift with your legs.

2) Bend your knees in a semisquat position, then hft your pack onto one of your thighs. Slide your right arm into the right strap. With the strap and the pack's weight on your right shoulder, swing the pack around and onto your back while sliding your left arm into the left strap.

—Dave Getchell and Steve Howe

REPRINTED FROM BACKPACKER MAR 94

Trial # 1

Please answer these questions by circling the most appropriate number based on the scale.

1	2	3	4	5	6	
Totally Unacceptable	Quite Unacceptable	Somewhat Unacceptable	Somewhat Acceptable	Quite Acceptable	Totally Acceptable	
Station # 1 : Bent Balance Beam / Boulder Hopping In this marching order : 1. My balance while jumping between boulders is : 1 2 3 4 5 6 2. My ability to balance while running on the beam is : 1 2 3 4 5 6						Time In __ : __ Time Out __ : __
Temperature (Right Ear)						°C
Comments :						

Please answer these questions by circling the most appropriate number based on the scale.

1	2	3	4	5	6	
Totally Unacceptable	Quite Unacceptable	Somewhat Unacceptable	Somewhat Acceptable	Quite Acceptable	Totally Acceptable	
Station # 2 : Straight Balance Beam / Strain Gauge Readings In this marching order : 3. My ability to balance when running on the straight beam is : 1 2 3 4 5 6						Time In __ : __ Time Out __ : __
Strain Gauge Readings Gauge Number : _____ Location : _____ Gauge Number : _____ Location : _____						
Temperature (Right Ear)						°C
Comments :						

Please answer these questions by circling the most appropriate number based on the scale.

1	2	3	4	5	6
Totally Unacceptable	Quite Unacceptable	Somewhat Unacceptable	Somewhat Acceptable	Quite Acceptable	Totally Acceptable

Station # 3 : Fence Climb / Agility Run In this marching order : 4. My ability to quickly change direction in the agility run is : 1 2 3 4 5 6 5. My ability to climb the fence is : 1 2 3 4 5 6	Time In __ : __ Time Out __ : __
Temperature (Right Ear)	°C
Comments :	

Please answer these questions by circling the most appropriate number based on the scale.

1	2	3	4	5	6
Totally Unacceptable	Quite Unacceptable	Somewhat Unacceptable	Somewhat Acceptable	Quite Acceptable	Totally Acceptable

Station # 4 : Side Slope Walk / Forward Ramp Climb/ Strain Gauge Reading In this marching order : 6. My ability to balance while running across the side slope ramp is : 1 2 3 4 5 6 7. My ability to get going up the forward ramp quickly is : 1 2 3 4 5 6	Time In __ : __ Time Out __ : __
Strain Gauge Readings Gauge Number : _____ Location : _____ Gauge Number : _____ Location : _____	
Temperature (Right Ear)	°C
Comments :	

Please answer these questions by circling the most appropriate number based on the scale.

1	2	3	4	5	6
Totally Unacceptable	Quite Unacceptable	Somewhat Unacceptable	Somewhat Acceptable	Quite Acceptable	Totally Acceptable

Station # 5 : Static Tasks In this marching order : 8. My range of motion is : 1 2 3 4 5 6 9. The system integration with the battle order is : 1 2 3 4 5 6	Time In __ : __ Time Out __ : __
Temperature (Right Ear)	°C
Comments :	

Marching Order - Static Tasks Questionnaire 1

Please rate your range of motion in this marching order for the following movements :

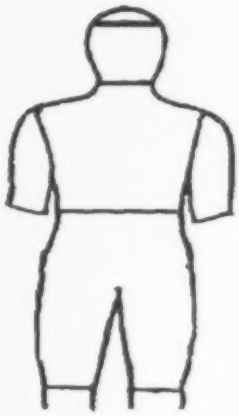
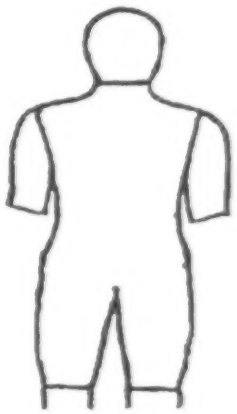
1	2	3		4		5	6
Totally Unacceptable	Quite Unacceptable	Somewhat Unacceptable		Somewhat Acceptable		Quite Acceptable	Totally Acceptable
1. Hands above head :		1	2	3	4	5	6
2. Hands in front :		1	2	3	4	5	6
3. Forward flexion :		1	2	3	4	5	6
4. Lateral bending :		1	2	3	4	5	6
5. Rotation :		1	2	3	4	5	6
6. Sit down :		1	2	3	4	5	6
7. Lie in prone position :		1	2	3	4	5	6
8. Emergency doff pack :		1	2	3	4	5	6
Comments :							

Marching Order

Extended March Questions

1. Please answer these questions by circling the most appropriate number on the scale.

1	2	3	4	5	6
Totally Unacceptable	Quite Unacceptable	Somewhat Unacceptable	Somewhat Acceptable	Quite Acceptable	Totally Acceptable
1. Overall acceptability of marching order for load carriage tasks :					
1	2	3	4	5	6
2. System integration of marching and battle order during extended march :					
1	2	3	4	5	6
3. Ease of mobility in marching order for extended march :					
1	2	3	4	5	6
4. Level of physical comfort wearing marching order during extended march :					
1	2	3	4	5	6
5. Level of thermal comfort wearing marching order during extended march :					
1	2	3	4	5	6

Front	Back
	
0 - 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 No Discomfort — Moderate Discomfort — Extreme Discomfort	0 - 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 No Discomfort — Moderate Discomfort — Extreme Discomfort

6. Please indicate areas of physical discomfort and rate the level of discomfort.

7. Are there any features you particularly like about this marching order ?

8. Are there any aspects you dislike about this marching order ?

9. Did you feel this marching order was well packed for you ? (was the centre of gravity in a comfortable location ?)

10. Please give any additional comments you have concerning this marching order.

Battle Order

Circuit Stations

Battle Order - Agility Station Questionnaire 1

Please answer these questions by circling the most appropriate number based on the scale.

1 Totally Unacceptable	2 Quite Unacceptable	3 Somewhat Unacceptable	4 Somewhat Acceptable	5 Quite Acceptable	6 Totally Acceptable	Time
Station # 1 : Horizontal Mouse Hole						
In this battle order :						In
1. My ability to enter this mouse hole is :						_ : _
1	2	3	4	5	6	Out
2. My ability to exit this mouse hole backwards is :						_ : _
1	2	3	4	5	6	
Comments :						

Please answer these questions by circling the most appropriate number based on the scale.

1	2	3	4	5	6	
Totally Unacceptable	Quite Unacceptable	Somewhat Unacceptable	Somewhat Acceptable	Quite Acceptable	Totally Acceptable	Time
Station # 2 : Vertical Mouse Hole						
In this battle order :						In _ : _
3. The difficulty of climbing to this mouse hole is :						
1	2	3	4	5	6	Out _ : _
4. My ability to pass through this mouse hole is :						
1	2	3	4	5	6	
Comments :						

Please answer these questions by circling the most appropriate number based on the scale.

1	2	3	4	5	6	
Totally Unacceptable	Quite Unacceptable	Somewhat Unacceptable	Somewhat Acceptable	Quite Acceptable	Totally Acceptable	Time
Station # 3 : Leopard Crawl						
In this battle order :						In
5. My level of discomfort when maintaining a low crawl position is :						_ : _
1	2	3	4	5	6	Out
6. My ability to leopard crawl with any speed is :						_ : _
1	2	3	4	5	6	
Comments :						

Please answer these questions by circling the most appropriate number based on the scale.

1	2	3	4	5	6	
Totally Unacceptable	Quite Unacceptable	Somewhat Unacceptable	Somewhat Acceptable	Quite Acceptable	Totally Acceptable	Time
Station # 4 : Over and Under In this battle order : 5. My ability to pass under the low obstacle is : 1 2 3 4 5 6 6. The difficulty I have in standing between the obstacles and scaling the fence is : 1 2 3 4 5 6						In _ : _ Out _ : _
Comments :						

1	2	3	4	5	6
Totally Unacceptable	Quite Unacceptable	Somewhat Unacceptable	Somewhat Acceptable	Quite Acceptable	Totally Acceptable

Battle Order - Static Tasks Questionnaire 1

Please rate your range of motion in this marching order for the following movements :

1 Totally Unacceptable	2 Quite Unacceptable	3 Somewhat Unacceptable	4 Somewhat Acceptable	5 Quite Acceptable	6 Totally Acceptable
1. Hands above head :	1	2	3	4	5	6
2. Hands in front :	1	2	3	4	5	6
3. Forward flexion :	1	2	3	4	5	6
4. Lateral bending :	1	2	3	4	5	6
5. Rotation :	1	2	3	4	5	6
6. Sit down :	1	2	3	4	5	6
7. Lie in prone position :	1	2	3	4	5	6
8. Prone grenade toss :	1	2	3	4	5	6
9. Prone rifle fire :	1	2	3	4	5	6
10. Prone ammunition access :	1	2	3	4	5	6
11. Canteen access :	1	2	3	4	5	6
12. Respirator access :	1	2	3	4	5	6

Battle Order

FAST Trial Questions

1. Please answer these questions by circling the most appropriate number on the scale.

1	2	3	4	5	6
Totally Unacceptable	Quite Unacceptable	Somewhat Unacceptable	Somewhat Acceptable	Quite Acceptable	Totally Acceptable
1. Overall acceptability of battle order for agility tasks :					
1	2	3	4	5	6
2. Durability of battle order during agility tasks :					
1	2	3	4	5	6
3. Ease of mobility in battle order for agility tasks :					
1	2	3	4	5	6
4. Level of physical comfort wearing battle order for agility tasks :					
1	2	3	4	5	6
5. Level of thermal comfort wearing battle order for agility tasks :					
1	2	3	4	5	6

Front	Back
0 - 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 No Discomfort Moderate Discomfort Extreme Discomfort	0 - 1 - 2 - 3 - 4 - 5 - 6 - 7 - 8 - 9 No Discomfort Moderate Discomfort Extreme Discomfort

6. Please indicate areas of physical discomfort and rate the level of discomfort.

7. Are there any features you particularly like about this battle order ?

8. Are there any aspects you dislike about this battle order ?

9. Please give any additional comments you have concerning this battle order.

Overall Summary

1. Please rate the military systems that you tested according to personal preference. Do not rate the packs that you did not wear during the testing.

1= liked most < ——————————— > 4 = liked least

	Attribute			
Marching Order System	Balance	Comfort	Fit	Manoeuvrability
Pack A				
Pack B				
Pack C				
Pack CC				
Pack D				
Pack DD				
Pack E				

2. Please detail any aspects of the systems you particularly like or dislike.

Pack A

LIKED	DISLIKED

Pack B

LIKED	DISLIKED

Pack C

LIKED	DISLIKED

Pack CC

LIKED	DISLIKED

Pack D

LIKED	DISLIKED

Pack DD

LIKED	DISLIKED

Pack E

LIKED	DISLIKED

Notes

DOCUMENT CONTROL DATA SHEET

1a. PERFORMING AGENCY	2. SECURITY CLASSIFICATION
Queen's University, Kingston, Ontario	UNCLASSIFIED Unlimited distribution -
1b. PUBLISHING AGENCY	
DCIEM	

3. TITLE

(U) Research and Development of an Advanced Personal Load Carriage System Phases II and III Section C: Analysis of Seven Pack-Based Systems using Human FAST Trials

4. AUTHORS

J. Doan J. Stevenson T. Bryant E. Morin D. Andrews

5. DATE OF PUBLICATION	6. NO. OF PAGES
October 30 , 1997	84

7. DESCRIPTIVE NOTES

8. SPONSORING/MONITORING/CONTRACTING/TASKING AGENCY
Sponsoring Agency:
Monitoring Agency:
Contracting Agency :
Tasking Agency:

9. ORIGINATORS DOCUMENT NO.	10. CONTRACT GRANT AND/OR PROJECT NO.	11. OTHER DOCUMENT NOS.
Contract Report 2001-080	W7711-5-7273/001/TOS	

12. DOCUMENT RELEASABILITY

Unlimited distribution

13. DOCUMENT ANNOUNCEMENT

Unlimited announcement

14. ABSTRACT

(U) This section outlines the methodology used by the Ergonomics Research Group in conduction standardized human trials for the evaluation of load carriage systems (LCS). The results from these First Assessment and Standardized Testing (FAST) trials pertained to two areas of interest of the Advanced Personal Load Carriage Research group. Firstly, information on subject preferences was useful in increasing the knowledge of LCS design quality, and the effect of different designs and design interactions on human performance. Secondly, the FAST Trials proved human factors results for correlation with LC Sim data. Results from LC Sim testing can be found in Section B, while outcomes of the correlation analysis can be found in Section D. Specific areas of concern for this project included integration of marching orders, physical costs associated with the incorporation of fragmentation protection into the LCS, and the general performance of different marching and battle order designs. Twenty eight experienced military subjects were assigned four of the load carriage systems (LCS) over the course of four consecutive trials. In each trial, subjects completed a march of 5.0 km over level ground as well as five activity stations (AS). Each lap of the march (1.0 km) was followed by one of these AS's, presented to the subjects in random order. Subject responses were elicited immediately following each AS. Following one complete trial, a subjective response summary was collected, rating the acceptability of the LCS. Subjects also rated their perceived discomfort, due to the LCS, experienced during the test. After doffing the test ruck, subjects completed five different AS's designed to test features and function of the battle order component of the test LCS. Again, subjective response was gathered pertaining to performance in each test, overall impressions, and perceptions of discomfort. Following completion of four trials subjects ranked the four LCS's they tested in terms of balance, comfort, fit, and manoeuvrability.

15. KEYWORDS, DESCRIPTORS or IDENTIFIERS

(U)

#516230

CA011659